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A small natural run of adult pink salmon (Oncorhynchus gorbuscha) to Sashin Creek in Southeastern Alaska was supplemented in 1964 through a transplantation of adult pink salmon from Bear Harbor on Kuiu Island (Figure 1). Purpose of the transplantation was twofold: (1) To evaluate the feasibility of transplanting adult pink salmon from one stream to another, and (2) to reestablish a sizable run of pink salmon in an essentially barren stream. Methods of transplanting adults, observations on their distribution on the spawning ground, and survival of their progeny in fresh water are described in this report.

In managing pink salmon we are commonly faced with a scarcity of spawners in certain streams and an abundance in others. In some streams this is a cyclic occurrence; pink salmon are abundant and scarce in alternate years, a situation which may persist for a decade or longer. One stream where such a disparity has existed since 1950 is Sashin Creek near Little Port Walter on southern Baranof Island (Figure 1).

Since 1934 the U.S. Bureau of Commercial Fisheries has counted the adult pink salmon entering Sashin Creek as they passed a weir located at the head of tidewater. These counts have shown that spawners were abundant in both even- and odd-numbered years before 1945, but between 1942 and 1946 the even-year broods declined from 92,000 to fewer than 1,000 spawners. The odd-year broods also declined in that same general period (between 1941

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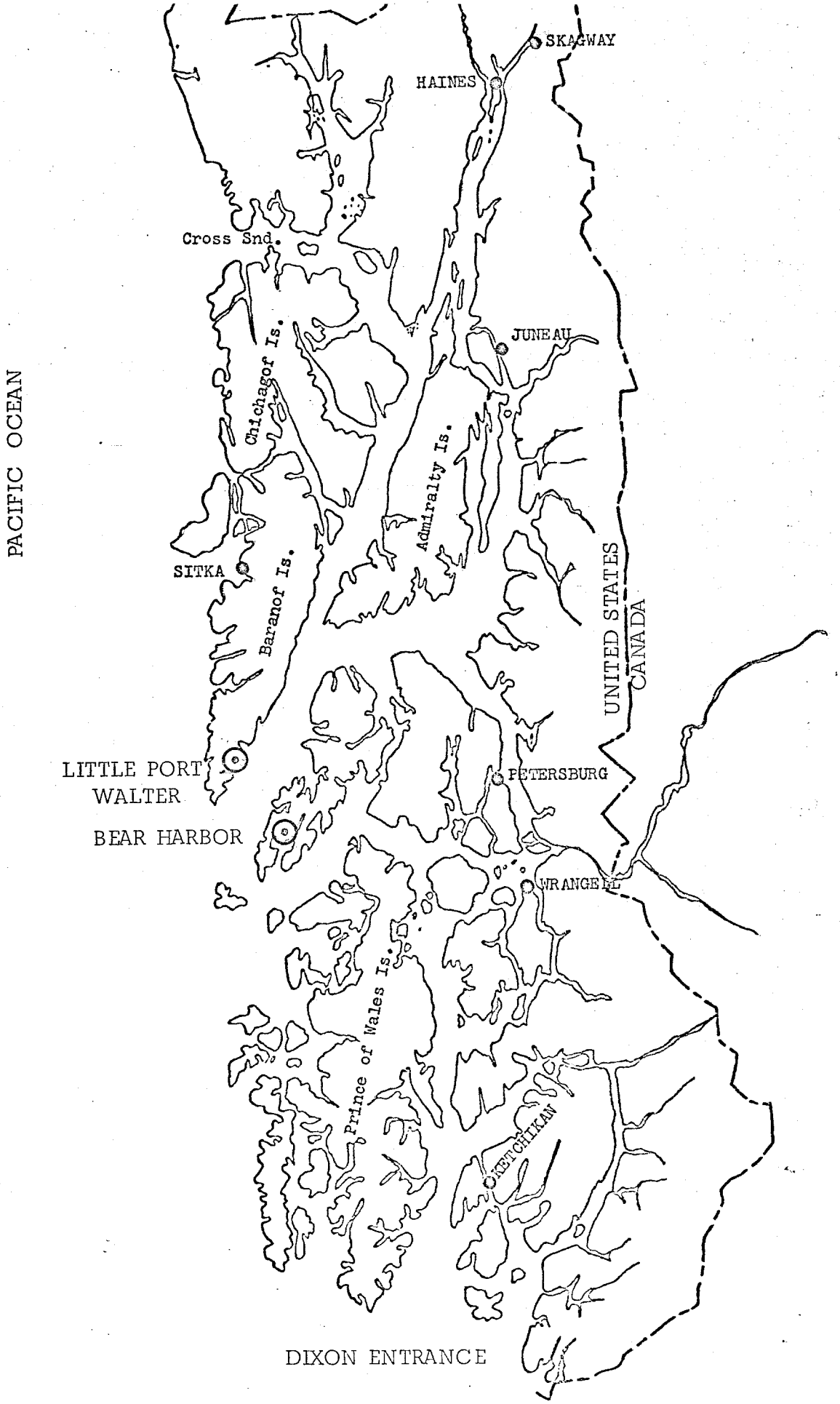

Figure 1. Map of Southeast Alaska showing locations of Little Port Walter and Bear Harbor.

and 1957), but they again became abundant after 1957 and now constitute the dominant cycle (Figure 2).

Three attempts were made to annihilate the even-year broods at Sashin Creek (1950, 1960, and 1962) by destroying fry and unspawned adults at the weir. Only a few adult pink salmon appeared in these years -- 112 in 1950, 162 in 1960, and 8 in 1962. Attempts at annihilating these small runs were made to study the possible straying and repopulation of a barren stream by pink salmon. These attempts undoubtedly played a part in keeping even-year broods at low levels after 1950. There is evidence that since that time even-year pink salmon spawners may have been largely fish originating from other streams (Harry and Olson, 1963).

TRANSPLANTATION OF SPAWNERS

Past efforts to establish and increase pink salmon runs have usually involved transplantation of eyed eggs or fry, often with disappointing results. Causes of failure are seldom clear, but it is conceivable that they are associated with improper handling of eggs or the unnatural rearing of young fish. If normal spawning behavior resulted through the introduction of transplanted adults, such problems would be avoided.

The recent use of the "brine boat" in Southeastern Alaska presented a practical vehicle for transporting live salmon. Such vessels were developed to carry loads of dead salmon in large tanks filled with refrigerated and recirculated sea water. Their use for transporting live fish required only a minor modification in the application of existing equipment. Pumps normally used to fill the vessel's tanks with sea water were used to provide a constant flow of fresh sea water for live fish in transit. For maximum circulation, water should enter at the bottom of the tank and overflow at the top. Tanks should be located above deck to permit unloading by flushing through openings at the bottom. This avoids dip netting fish from the tanks and allows rapid unloading via flumes.

The brine boat was first used by the Alaska Department of Fish and Game to transport live salmon in 1962. In this pilot study, 156 adult pink salmon were captured with a purse seine, placed in brine tanks, and transported 20 miles from Tamgas Harbor, Annette Island, to Bostwick Inlet, Gravina Island, in Southeastern Alaska. They were marked and were then released in about 2 fathoms of water near the mouth of Bostwick Inlet Stream. Eight of the marked salmon were observed spawning in the Bostwick Inlet Stream 1 week later. Two things were learned from the pilot study: (1) Small numbers of adult pink salmon could be captured and transported live with equipment commonly available on fishing grounds, and (2) at least some fish released off the mouth of a recipient stream would ascend the stream and spawn.

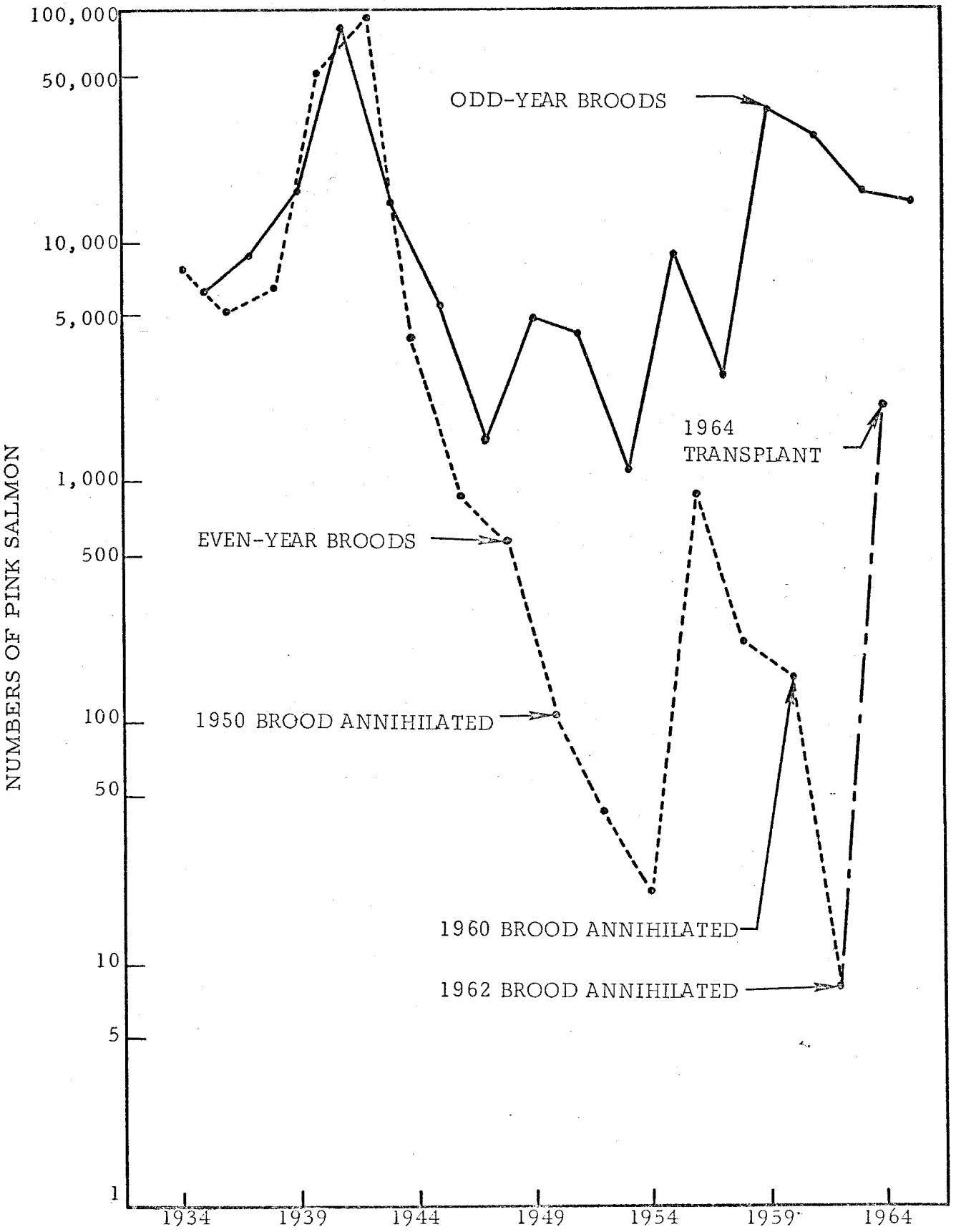

Figure 2. Number of pink salmon spawners: Sashin Creek, 1934-1963 (1964 transplant added).

Preparations

A cooperative study by the Alaska Department of Fish and Game and the U.S. Bureau of Commercial Fisheries to more thoroughly evaluate transplanting adult pink salmon was planned in 1963. Sashin Creek was selected as the recipient stream because of the presence of a weir to retain the adult fish and the availability of research personnel to evaluate spawning of the adults and survival of their progeny in fresh water. Transplantation of adult pink salmon was scheduled for 1964, when the natural run to Sashin Creek would be very small because of previous attempts to annihilate the even-year broods (Figure 2).

Personnel of the Alaska Department of Fish and Game were to select a source of fish and arrange for their capture and transportation to Little Port Walter Bay. Little difficulty was anticipated in obtaining equipment satisfying our need, since representatives of the Alaska salmon industry had indicated a willingness to assist with the capture and transport of the fish. New England Fish Company had agreed in advance of the fishing season to provide a brine boat, but it later became necessary for them to divert their vessel to distant fishing grounds. Another vessel, the JACK B, was subsequently loaned to the project free of charge by Pacific American Fisheries, Inc.

The JACK B was at Bear Harbor, Affleck Canal, some 50 water miles distant from Little Port Walter on the morning of August 24, when personnel directing the project left Juneau and Petersburg in small float planes. An area closed to commercial fishing extends from the head of Bear Harbor southward about 1 mile. Several commercial seine boats were fishing in waters south of the closed area. Fish were observed from the air throughout the closed section, and a school estimated to contain in excess of 15,000 pink salmon was near the head of the bay. The transplanted fish were seined from this large school.

The JACK B

The JACK B had two brine tanks above deck just forward of the wheelhouse which could be unloaded from the bottom by flushing their contents through hydraulically operated gates located at deck level. The tank contents emptied into a narrow passageway forward of the tanks and could be directed overboard to either side via a portable flume. The JACK B was also equipped with a brail or large dip net attached to a hydraulically operated boom which could be used to dip fish from the seine. The brail is emptied through the bottom by releasing a drawstring.

Dimensions of each deck tank were 6 X 6 X 24 feet, a volume of 864 cubic feet or a capacity of 6,500 gallons. Each tank had a 30-inch square loading hatch at the top. Water entered the tanks through perforations in 2 inch

diameter pipes on 3 sides of the bottom. Fresh sea water could be pumped through the tanks after they had been filled to capacity at the rate of 220 g.p.m. Water overflowed at the top loading hatch and spilled back into the sea. No concern was felt regarding foreign substances such as zinc in the system because of the large volume of water exchanged.

Capture and loading of salmon

The captain of the commercial purse seiner M/V TONKA, which was fishing in Bear Harbor, agreed to capture fish for us from the large school of salmon in the closed area at the head of the bay. Several thousand salmon were encircled by the seine and concentrated in a bag alongside the TONKA (Figure 3). The TONKA and the captured fish were then towed by her seine skiff into position beside the JACK B for loading the tanks.

The two deck tanks aboard the JACK B were flushed and refilled with fresh sea water. The pink salmon were brailed from the TONKA's seine and emptied into the tanks (Figure 4). The brail was alternately emptied into the port and starboard tank until an estimated 1,500 fish had been placed in each (Figure 5). We later found that the total load had been over-estimated by 600 fish. No attempt was made to maintain a 1:1 sex ratio--males spilling out of the brail were thrown overboard but females were kept (Figure 6).

Ninety minutes were required for the operations at Bear Harbor -- 20 minutes to catch the fish, 25 minutes to tow the TONKA and her catch to the JACK B, and 45 minutes to load the fish into the tanks. The JACK B departed Bear Harbor for Little Port Walter at approximately 1045 hours.

The trip

Water temperature in the tanks fluctuated between 55° at Bear Harbor and 51°F in Chatham Strait 5 miles northwest of Cape Decision. Turbidity limited visibility to the surface of the tanks during the first 4 hours of the trip. During the period of low visibility only one fish showed distress by swimming aimlessly at the surface and most fish were assumed to be in satisfactory condition.

By 1500 hours, in mid Chatham Strait, the water in the tanks had cleared sufficiently to permit observation of fish at the bottom of the tanks. Most fish appeared to be swimming normally; but also visible, particularly in the starboard tank, was an undetermined number of dead fish. Continued observations were made while the water remained clear, but no additional mortality or sign of distress was noted.

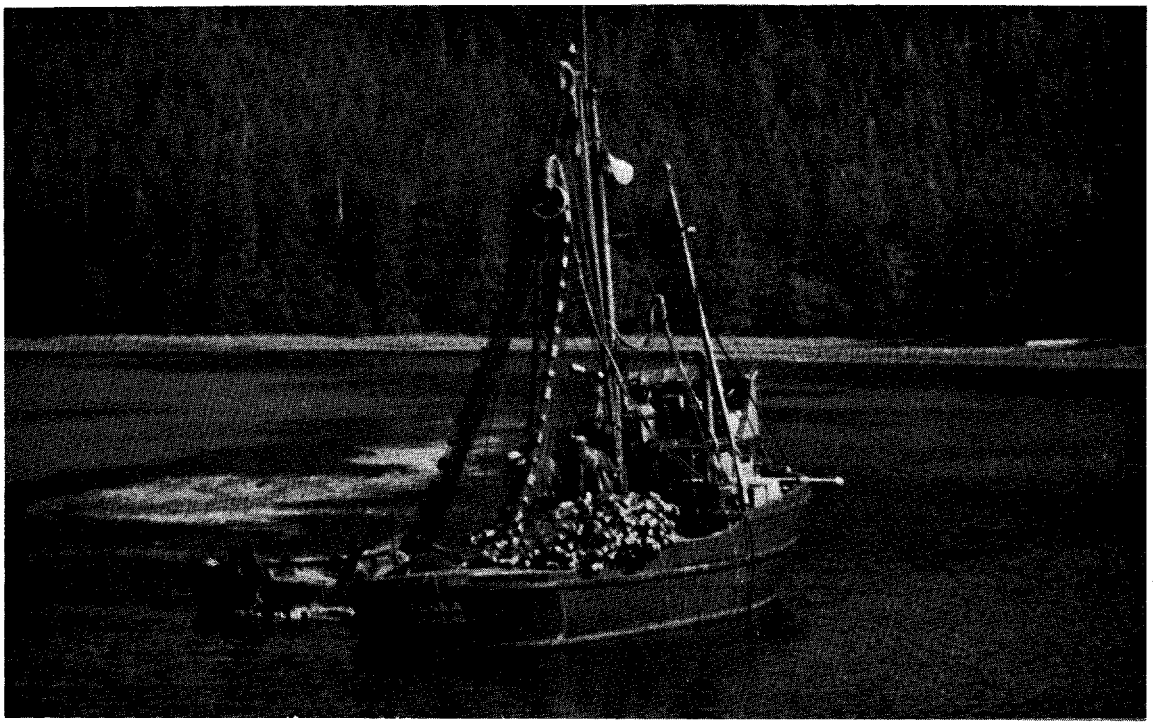

Figure 3. The purse seiner TONKA with all but the "money bag" aboard.

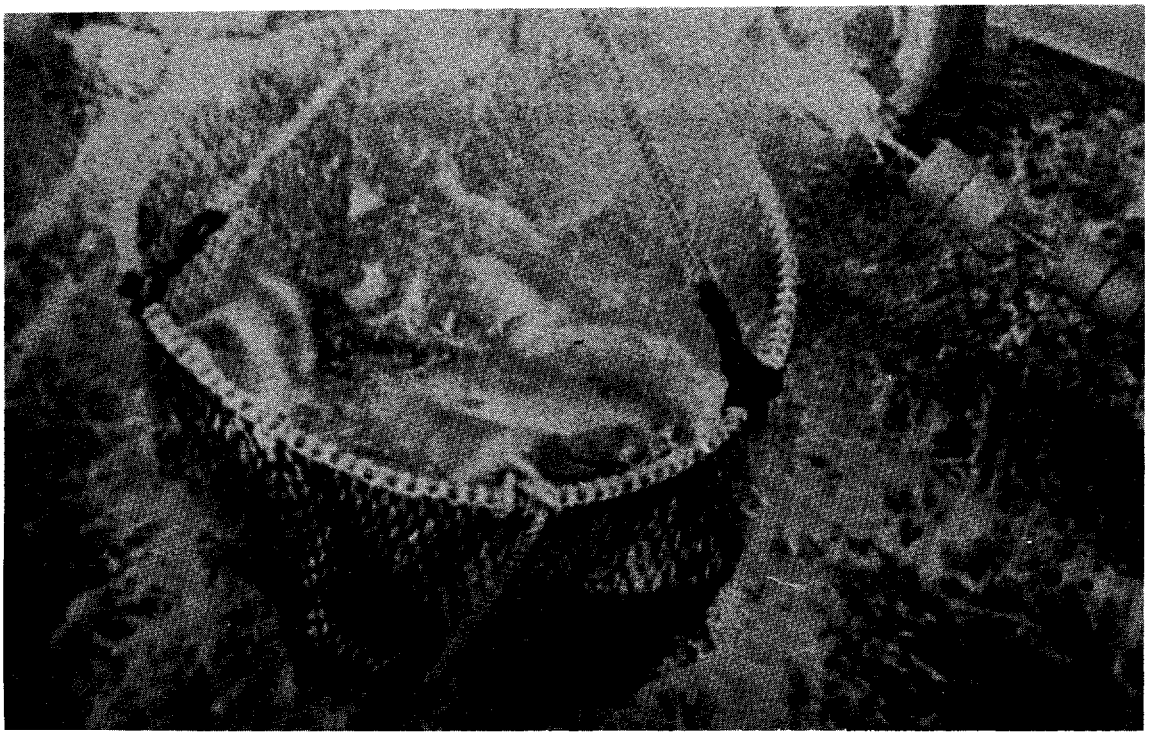

Figure 4. Brailing fish from the seine to the JACK B's tanks.

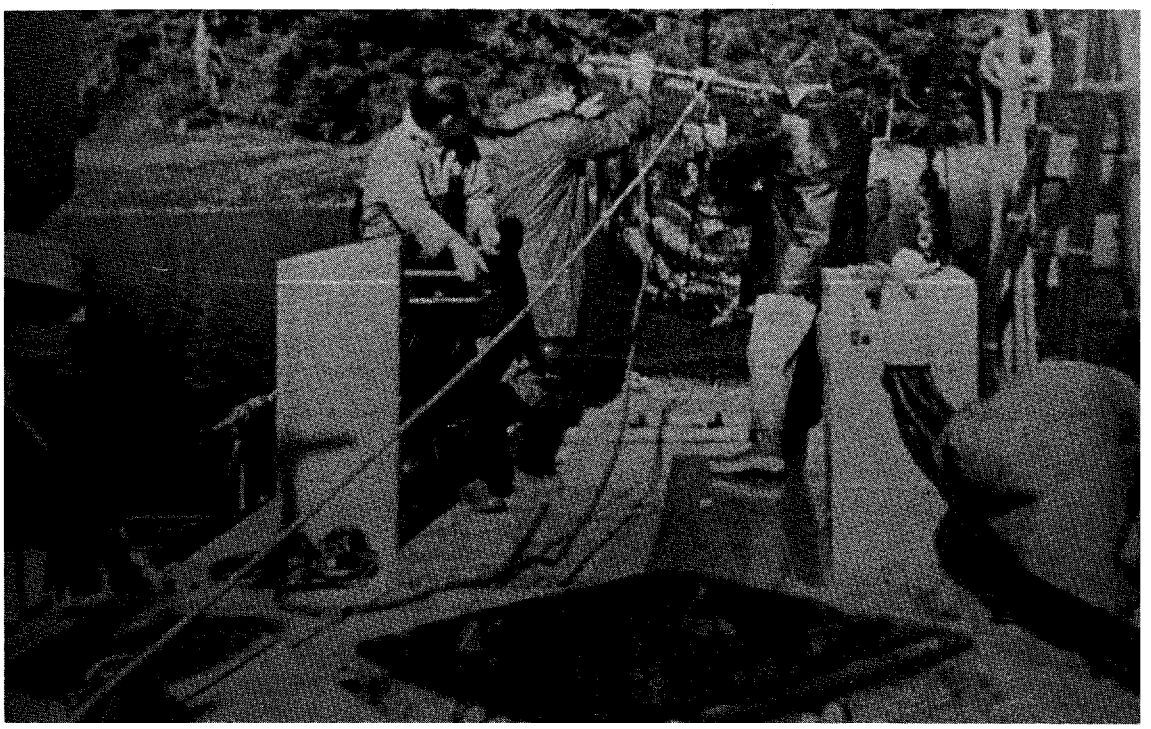

Figure 5. A brail load over the far tank. Loading hatch of the near tank at bottom center.

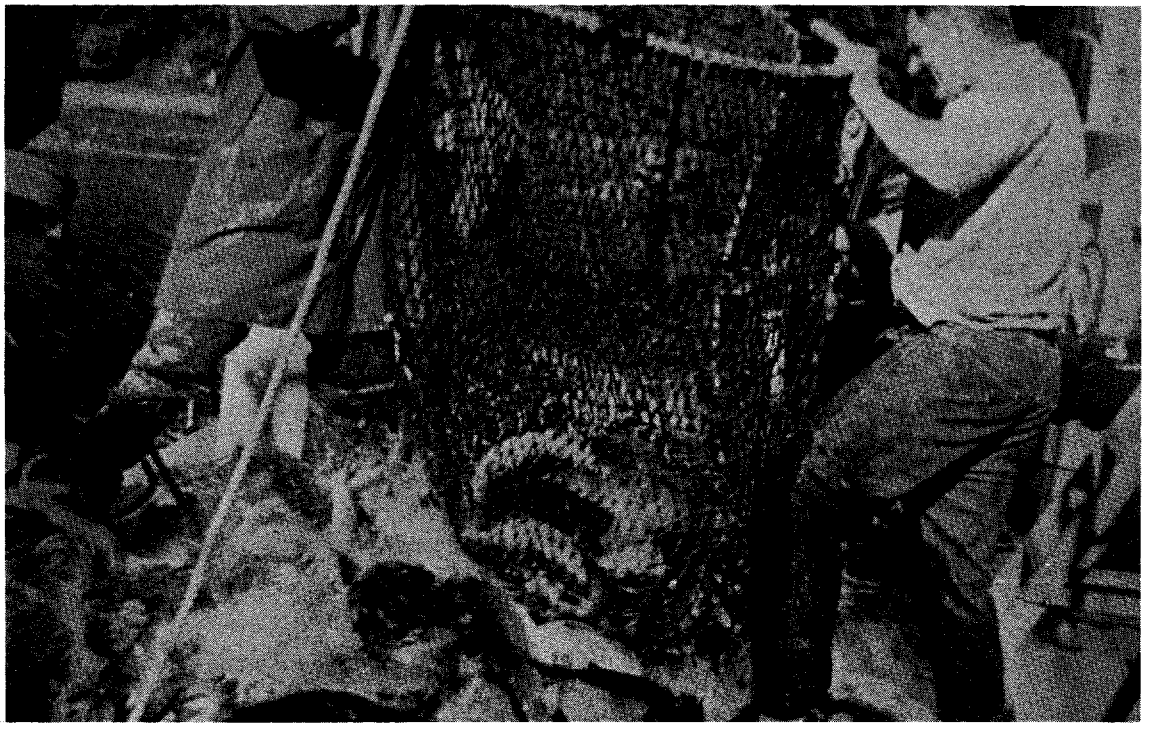

Figure 6. Releasing a brail load into the near tank. Spilled males discarded, females kept.

At 1745 hours, approximately 7 hours after departing Bear Harbor, the JACK B arrived at Little Port Walter and tied up alongside a net enclosure which was constructed of four log rafts decked over with 2 X 12 inch planks and arranged to form a pound about 35 feet square (Figure 7). Suspended inside the enclosure was a 6 foot deep bag of 1 inch square-mesh herring net. The JACK B was immediately unloaded by opening the bottom gate of each tank and allowing the contents to spill overboard into the net pound through a flume (Figure 8).

Moving the transported salmon into Sashin Creek was begun late in the afternoon of August 25 and completed on August 28. The fish were dipped into small floating pens having dimensions of 6 X 10 X 3 feet, towed to the mouth of the creek, and passed over the existing weir. About 30 minutes were required to transport each load of fish between the pound and the weir.

A total of 2,395 pink salmon were transported from Bear Harbor to Little Port Walter, and 1,866 were released above the weir in Sashin Creek. An additional 150 males were tagged and released in the bay, 36 males and females escaped into the bay from the floating pens, and total mortality amounted to 343 (Table 1).

Of the mortality, 103 were males and 240 were females. Almost all (238) of the loss occurred while the fish were in transit and is believed to have been caused by overloading of the brail while transferring fish from seine to tanks.

Table 1. Adult pink salmon transported from Bear Harbor to Little Port Walter.

Date	Released live in Sashin Cr.		Tagged and released in bay		Escaping live and untagged in bay		Number dying	
	Male	Female	Male	Female	Male	Female	Male	Female
Aug. 23							101	237
24								
25	48	90			3	1		
26	154	254			20	5		1
27	340	488			5	2		1
28	185	307	150				2	1
Total	727	1,139	150		28	8	103	240

Number transported to Little Port Walter:
1,008 males
1,387 females
2,395

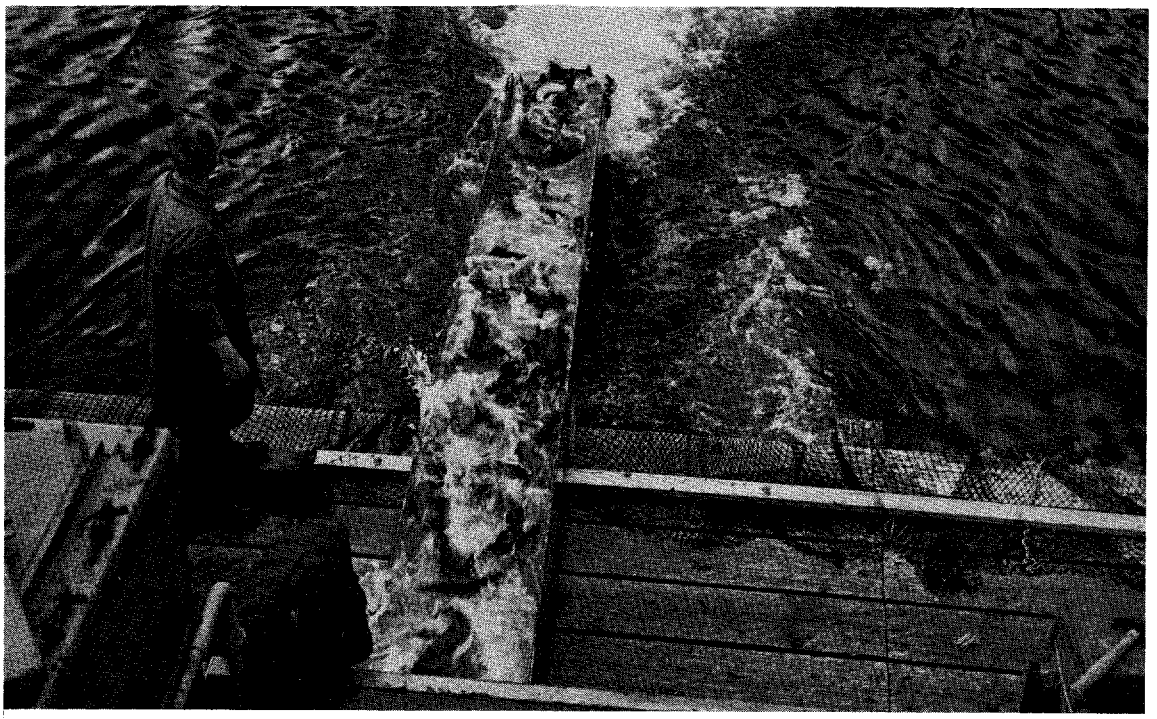

Figure 7. Flushing the salmon from the JACK B's tanks into the herring net pound.

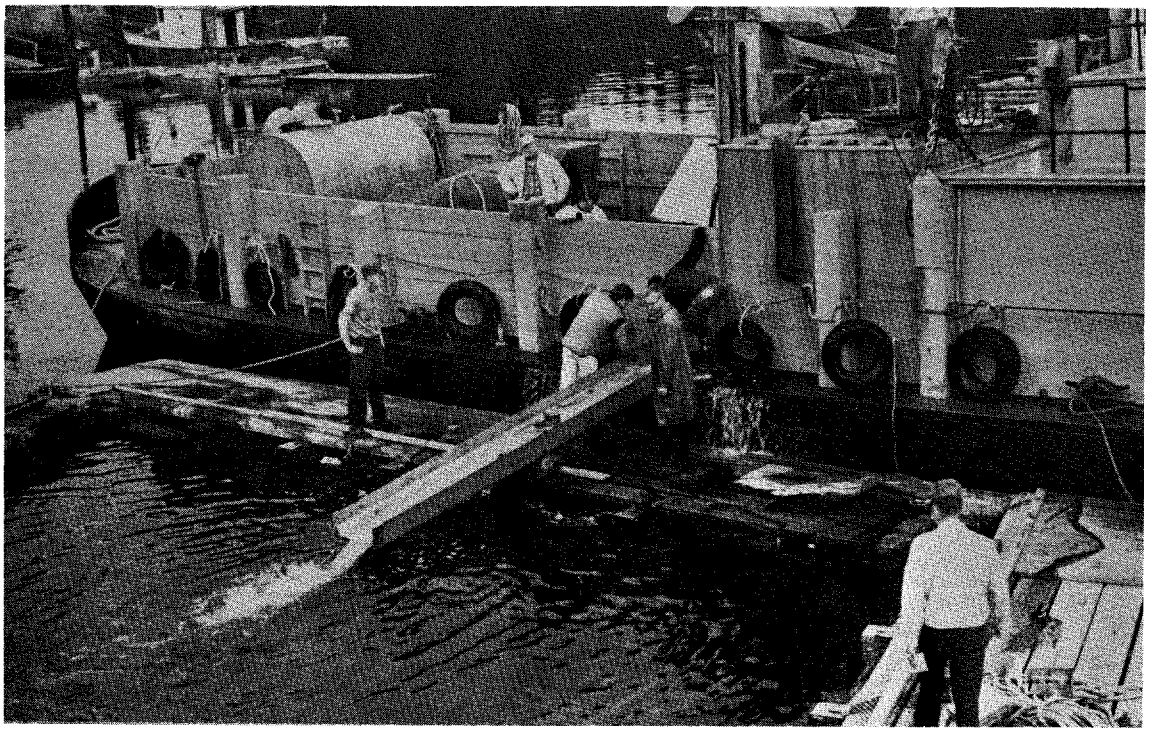

Figure 8. The last fish of the load. Showing the forward part of the JACK B. One of the tanks showing above and behind the flume.

DISTRIBUTION OF SPAWNERS

The Sashin Creek spawning ground occurs over a reach of stream extending 3,100 feet upstream from the weir and includes 147,000 square feet of stream bed. Fish can migrate 4,000 feet upstream from the weir to a waterfall. The upper 900 feet of the stream accessible to salmon are mostly unsuitable for spawning use.

Observations on spawners were made in four study sections which included 97 percent of the area utilized. Information on surface area, location, gradient, and size of bed materials is given for each study section in Table 2.

Fish began moving upstream from the weir within 24 hours of their release. Unspawned salmon normally occupy six pools above the weir. One pool is adjacent to the weir and the others are 1,200, 2,000, 2,400, 2,600 and 3,100 feet upstream. The number of fish occupying each of these pools was estimated through August 29 to evaluate their upstream movement (Table 3).

Between August 30 and September 19, 327 adult pink salmon (161 males, 166 females) passed through the weir to enter Sashin Creek of their own volition. Of this number, 40 were from the group of 150 males tagged and released in the bay. The remainder were presumed to have originated in other streams and to have strayed into Sashin Creek, because to our knowledge all eight of the pink salmon spawners appearing in 1962 had been destroyed.

There were 2,193 pink salmon spawners in Sashin Creek in 1964, of which 1,305 were females. The first female occupied the spawning ground August 28, and the die-off of spawned pink salmon was complete by October 3.

The peak of spawning activity occurred September 16, when 695 females were counted on the spawning ground. This count does not include those in pools.

Distribution of the female spawners was recorded daily by counting the number of females on the spawning ground in the four study sections. The counts were made by experienced observers, and an estimate of the total number of females spawning within study area j (N_j) was calculated from a summation of the daily counts as follows:

$$N_j = 1{,}305 \text{ females entering } (0.97) \frac{\sum_{i=1}^{k} (N_j)_j}{\sum_{j=1}^{1} N_j}, \quad (1)$$

where i is an individual count ($k = 30$)

Table 2. Surface area, location, gradient, and amount of coarse materials in study sections of Sashin Creek.

Section	Surface area		Distance from weir		Average gradient	Amount of bed materials larger than 12.7 mm diameter
	Area	Portion of total spawning ground	Upper boundary	Lower boundary		
	Feet	Percent	Feet	Feet	Percent	Percent
I	31,700	22	3,100	2,500	0.7	81
II	43,780	30	2,500	1,600	.3	61
III	40,330	29	1,600	700		
IV	25,030	16	700		0	47
Total	140,840	97				

Table 3. Number of pink salmon from Bear Harbor observed in pools located various distances upstream from the weir at Sashin Creek.

Date	Pink salmon in pool at distance (feet)					
	0 ft.	1200 ft.	2000 ft.	2400 ft.	2600 ft.	3100 ft.
	Number	Number	Number	Number	Number	Number
August 25	138	0	0	0	0	0
26	541	5	0	0	0	0
27	1,354	20	0	0	0	0
28	1,769	60	25	10	2	0
29	1,676	150	25	10	2	3

j is an individual study area (1=4), and

N is the number of females counted.

The estimates indicate that the density of pink salmon spawners was highest in downstream section IV and lowest in upstream section I (Table 4). The fish tended to occupy sites near the weir for spawning rather than sites remote from the weir.

SURVIVAL OF EGGS AND ALEVINS

Freshwater survival of pink salmon in Sashin Creek has been estimated since 1940 by counting the number of fry migrating to the estuary and dividing this number by potential egg deposition. The weir used for counting fry was damaged by ice in winter 1965 and was inoperable in the spring during fry migration, so we estimated freshwater survival from the number of alevins in spawning beds just before the fry emerged.

Spawning beds were sampled in early April with a hydraulic sampler (McNeil, 1964), and 310,000 live alevins were estimated from the arithmetic sample counts. The 90 percent confidence interval estimate of the total number of alevins, calculated from log-transformed counts (McNeil, 1964) was

$$180{,}000 < \mu < 390{,}000$$

Potential egg deposition was estimated to be 2,230,000. This figure is obtained by multiplying the number of females in Sashin Creek (1,305) by their fecundity (1,709 eggs). Fecundity was determined from examination of 25 unspawned females from Bear Harbor.

Mean freshwater survival through early April was estimated to be

$$\left(\frac{310{,}000}{2{,}230{,}000}\right) \quad (100) = 13.9 \text{ percent.}$$

The 90 percent confidence interval estimate of survival was $8.1\% < \mu < 17.5\%$.

Estimates of survival of pink salmon before fry emerge and after they migrate have previously been in close agreement in Sashin Creek (Table 5). Estimates with the hydraulic sampler are for late March or early April. Fry commonly emerge and migrate to sea between mid April and early June. Agreement between the two methods of making estimates is considered to be good, and survival estimated with the hydraulic sampler in early spring appears to be representative of freshwater survival through late spring.

Table 4. Estimates of the number of female pink salmon spawners in each of four sections of Sashin Creek, 1964.

Section	Total females	Surface area	Females per 100 square feet
	Number	Feet	Number
I	39	31,700	0.1
II	386	43,780	0.9
III	446	40,330	1.1
IV	395	25,030	1.6

Table 5. Survival of pink salmon in Sashin Creek estimated before fry emerge (hydraulic sampler) and after fry migrate (weir).

Brood Year	Survival estimates	
	Hydraulic sampler	Weir
	Percent	Percent
1959	11.0	13.2
1961	21.4	20.2
1962	0	1.2
1963	20.7	19.6

Freshwater survival of the 1964 brood was higher than the 6.3 percent average of 22 previous broods (Table 6). Prior to 1964, freshwater survival of the progeny from even-year spawning was less than average. The progeny of the odd-numbered brood years, on the other hand, have experienced greater than average survival since 1951.

There has been a scarcity of fry from spawning in even-numbered years for almost 2 decades (Table 6). The relatively high freshwater survival of the introduced 1964 brood year resulted in the largest number of fry from an even-numbered brood since 1942. If at least 1 percent of fry migrating to sea in spring 1965 return to Sashin Creek as adults in summer 1966, they will be more numerous than the parent spawners.

Periods of high mortality of the 1964 brood year in fresh water were identified by collecting samples with the hydraulic sampler in late September (end of spawning) and early April (beginning of fry emergence). Figure 9 illustrates the survivorship curve for 1964 brood pink salmon in Sashin Creek from potential egg deposition to fry emergence.

Ninety-eight percent of 2,300 eggs collected by sampling 261 random points in late September were alive, so the relatively low percentage of males in the population of spawners (42 percent) did not result in an unusually high percentage of unfertilized eggs. The lowest density of eggs occurred in section I and the highest in section IV (Table 7), which was anticipated from the distribution of spawners.

Live embryos at the end of spawning were estimated from the arithmetic sample counts to be 55 percent of potential egg deposition. Forty-four percent of potential egg deposition disappeared during spawning but less than one percent of potential egg deposition was retained by the spawned females. Forty spawned females were examined, and the 90 percent confidence interval estimate of the number of eggs retained per female was $5 < \mu < 17$. Therefore, most of the eggs that disappeared during spawning had been voided. An estimated 25 percent of the live embryos in the spawning beds in late September survived to early April. The lowest density of alevins at the beginning of fry emergence was in section I and the highest in section IV (Table 7). Hence, the relatively high density of live embryos and alevins in the downstream study section did not change appreciably from spawning to fry emergence.

DISCUSSION AND CONCLUSIONS

Development of an inexpensive method for transplanting adult pink salmon to streams receiving too few spawners could be beneficial to the fishery.

Table 6. Survival of even- and odd-numbered brood year pink salmon in Sashin Creek.

Even Year				Odd Year			
Brood year	Potential egg deposition	Fry produced	Survival	Brood year	Potential egg deposition	Fry produced	Survival
	Number	Number	Percent		Number	Number	Percent
1940	52,858,000	3,400,000	6.4	1941	88,678,000	1,024,000	1.2
1942	78,894,000	674,000	0.8	1943	14,980,000	228,000	1.5
1944	3,904,000	106,000	2.7	1945	5,062,000	43,000	0.8
1946	736,000	1,200	0.2	1947	1,330,000	27,600	2.1
1948	516,000	9,100	1.8	1949	4,800,000	176,000	3.7
1950	86,000	50	0.1	1951	4,062,000	412,000	10.1
1952	No escapement			1953	1,284,000	95,400	7.4
1954	12,000	660	5.5	1955	10,286,000	1,266,000	12.3
1956	1,018,000	5,050	0.5	1957	2,588,000	563,000	21.8
1958	174,000	10,700	6.1	1959	40,379,000	5,332,000	13.2
1960	No escapement			1961	29,425,000	5,940,000	20.2
1962	8,000	100	1.2	1963	16,640,000	3,256,000	19.6
		Mean survival	2.5			Mean survival	9.5

Grand average = 6.3 percent

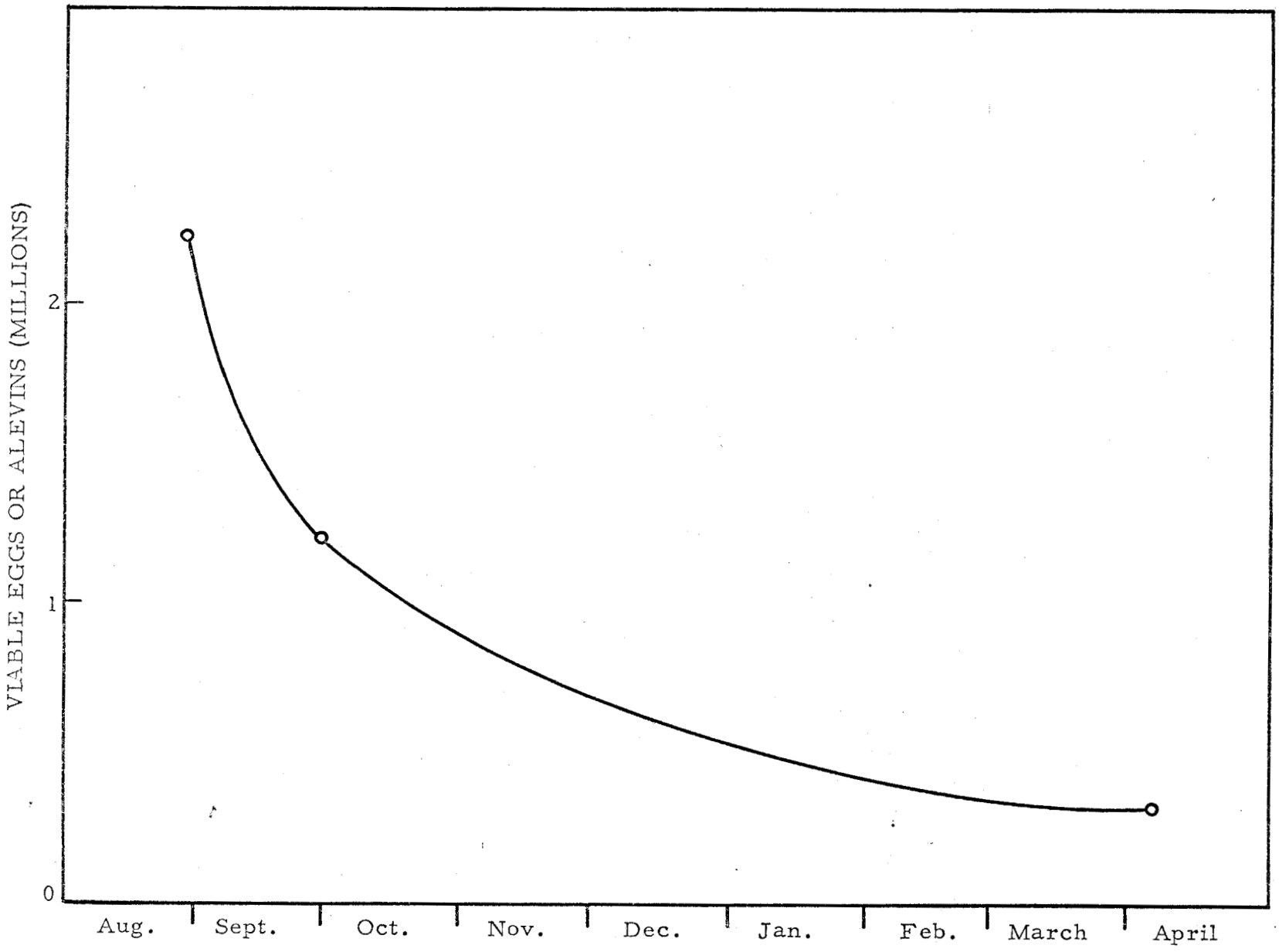

Figure 9. Survival from transplanted 1964 brood pink salmon, Sashin Creek.

Table 7. Density of 1964 brood year pink salmon in study sections between spawning and fry emergence, Sashin Creek.

Section	Estimated potential egg deposition per square foot	Estimated surviving embryos per square foot at end of spawning	Estimated surviving alevins per square foot at beginning of fry emergence
	Number	Number	Number
I	2.7	0	0.1
II	16.4	8.5	2.1
III	18.2	9.3	1.6
IV	25.1	10.0	5.5
Total stream	15.3	8.5	2.1

Our method involves capturing maturing pink salmon where spawners are abundant and releasing them in a stream where spawners are scarce. The fish are captured by seining, placed in the tanks aboard a brine boat, and provided a constant flow of fresh sea water. Seiners and vessels with brine tanks are commonly available on the fishing grounds when transplantation of adult pink salmon might be warranted.

Evaluation of techniques for transplanting adult pink salmon was undertaken by the Alaska Department of Fish and Game and the U.S. Bureau of Commercial Fisheries in 1964 at Sashin Creek after a pilot study by Alaska Department of Fish and Game in 1962. Evaluation will not be completed until the progeny of the transplanted adults return to Sashin Creek to spawn in the summer of 1966[2/]. The relative ease of transplanting adults from Bear Harbor to Sashin Creek, the successful spawning of the transplanted fish, and the good survival in fresh water of their progeny show the method has promise.

Each 6,500 gallon tank aboard the vessel JACK B maintained 1,000 live pink salmon for seven hours. Although there was mortality enroute to Little Port Walter, it is thought that most of the fish dying may have received internal injuries while being loaded at Bear Harbor. Each tank received a continuous inflow of 220 gpm of fresh sea water. The dissolved oxygen content of sea water was reduced from about 9 mg/l at the inlet to about 3 mg/l at the outlet of each tank. Transporting many more than 1,000 adults per tank of this size is not recommended unless the rate of water exchange is increased.

No serious difficulties were encountered in capturing the fish at Bear Harbor, transporting them to Little Port Walter, or releasing them in Sashin Creek. Presence of a large floating pound in Little Port Walter Bay allowed us to postpone moving the fish to Sashin Creek until high tide when it was most convenient to release them above the weir.

Release of 150 tagged males in Little Port Walter Bay confirmed indications from a study by the Alaska Department of Fish and Game in 1962 at Bostwick Inlet, Gravina Island, that some fish released in a bay will enter a nearby stream to spawn. In our study, 27 percent of the tagged males released in the bay entered Sashin Creek to spawn; only males were released. More detailed evaluation of movement of fish transported a considerable distance and released adjacent to a stream where spawners are scarce, seems warranted.

Actions of the transplanted adult pink salmon appeared normal. None of the fish were observed to seek a route through the weir in an attempt to return to the bay. Initially the fish remained schooled in a pool immediately

[2/] Preliminary figures on the returning run indicate that about 6,000 pink salmon spawners entered Sashin Creek in August and September 1966.

upstream from the weir. Some began migrating upstream to pools as distant as 3,100 feet from the weir within 20 hours of their time of release. Spawning began within 72 hours of their time of release.

Most of the spawning occurred in the downstream sections of Sashin Creek. This was not unusual, because spawning had occurred in the same area in other years when the spawning population was small.

Egg retention was less than 1 percent of potential egg deposition. A retention of 4 or 5 percent is common in fish native to Sashin Creek. An estimated 44 percent of potential egg deposition disappeared during spawning, but this is not unusual for pink salmon. Similar losses have been observed at Sashin Creek and elsewhere. Causes of egg disappearing during spawning are thought to include superimposition of redds and predation.

The estimated 14 percent freshwater survival of spawn from the pink salmon transplanted to Sashin Creek in 1964 was about double the long-term average in Sashin Creek. The highest observed survival was 22 percent for the 1957 brood and the lowest 0.1 percent for the 1950 brood.

Although the experimental transplantation of adult pink salmon and the subsequent spawning and development of their progeny in fresh water were successful, the transplantation may not be called a complete success until a self-perpetuating run becomes established. Failure to establish a run might result from unfavorable reactions to the new environment because of genetic characteristics of the transplanted fish. On the other hand a glance at Figure 2 will show that even genetically attuned fish may fail to provide an abundance of spawners consistently.

To minimize the chance of failure in establishing pink salmon runs by transplanting adults, the donor stock should have similar characteristics of timing of migration and spawning as the stock native to the recipient stream. Also it would be desirable for donor and recipient streams to have similar water temperatures and characteristics of spawning beds. In our study the transplanted fish spawned mostly in September, which is typical for pink salmon native to Sashin Creek. We were unable to obtain detailed information on physical characteristics of the donor stream, however.

Under no circumstance should pink salmon be moved indiscriminately, since there is the possibility of undesirable effects from the mixing of genetically dissimilar stocks. If a recipient stream is nearly devoid of spawners, (as in Sashin Creek), we forsee little danger from such interbreeding. However, if the recipient stream possesses a small population of spawners, one gambles with the possibility of introducing unfavorable genetic characteristics to the native population. Under these circumstances, we would favor giving the natural population protection from the fishery before attempting the introduction of spawning stock from another stream.

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